CP VIOLATING LEPTON ASYMMETRIES IN LEFT-RIGHT MODELS

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Abstract

Lepton charge asymmetries can be used as an alternative means of searching for new physics. They are interesting because they are small in the Standard Model and therefore, necessarily evidence new physics. In this work we explore the use of lepton asymmetries as a probe of the flavour structure of the left-right symmetric model with spontaneous CP violation. We find that new physics may enhance the magnitude of a_{SL} up to the precent level within the appropiate parameter space.

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1   Introduction

CP violation is one of the few remaining unresolved mysteries in particle physics. Since its discovery, no general agreement has been reached on its origin. The simplest and most widely accepted explanation is due to Kobayashi and Maskawa. In their model CP is explicitly broken by the Yukawa couplings and no other fields than those of the minimal Glashow-Salam-Weinberg model are required.

Although there is no conflict between the observation of CP violation in the kaon system and this theory, intriguing hints of other plausible explanations emerge from astrophysical consideration of the baryon to photon ratio in the Universe. On top of that, several extended models such as supersymmetric models [1], two Higgs doublet model [2], vector like quark models [3] and left-right symmetric models [4, 5, 6] (to mention only a few of them) can equally well explain the existing data. It is for that reason that exploration of CP violation in the B system is so crucial.

The B system offers several final states that provide a rich source for the study of this phenomenon. Even more, B factories will provide us a unique tool to study CP violation in the B system and, if we are lucky enough will gift us with the first evidence for physics beyond the Standard Model. Whatever the new physics will turned out to be, its detection would give information which will not be accessible to high energy colliders. For example, if our future shows itself as left-right symmetric, then a detailed study of the B system will give us the opportunity to catch a glimpse on the right-handed scale.

Particularly important are the processes for which the Standard Model predicts vanishing or negligible small results. In this case, both observation and non observation of such effects can be directly related to constrains on the physics which hides itself beyond the Standard Model. With this aim, the measurements of the dilepton charge asymmetry and the total lepton charge asymmetry may play a crucial role in distinguishing between non standard models of new physics.

These lepton asymmetries measure the relative phase between Γ_{12} and M_{12}. In the Standard Model, they have (to leading order) the same phase and therefore these asymmetries are strongly suppressed. In models of new physics, new contributions to mass mixing which would generally carry a different phase from that of the Standard Model, change completely the landscape. We will show that in the left-right symmetric model with spontaneous CP violation one would expect more than an order of magnitude enhancement over the Standard Model predictions for both B_d and B_s. We will also investigate the correlation between the CP asymmetry a_{SL} and the CP asymmetries in $B_d \rightarrow J/\psi \ K_s$ and $B_d \rightarrow \pi^+ \ \pi^-$.

The remainder of this paper is organized as follows. We begin in section 2 by presenting some necessary preliminarities to B^0-$\overline{B^0}$ mixing. The basic features of the left-right symmetric model with spontaneous CP violation as well as the new contributions of this model to B^0-$\overline{B^0}$ mixing are given in section 3. Section 4 contains the results and the analysis of the above mentioned correlation. Finally, we conclude in section 5.

2 The formalism

The general formalism to describe mixing among the neutral B^0 and $\overline{B^0}$ mesons is completely analogous to the one in the kaon system. Assuming CPT symmetry to hold, the 2×2 B^0-$\overline{B^0}$ mixing matrix can be written as

$$\mathcal{M} = \begin{pmatrix} M & M_{12} \\ M_{12}^* & M \end{pmatrix} - \frac{i}{2} \begin{pmatrix} \Gamma & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma \end{pmatrix} \tag{1}$$

where the diagonal elements M and Γ are real parameters. If CP were conserved, M_{12} and Γ_{12} would also be real.

So far everything looks similar to the kaon system, however, in the B system, the physical mass eigenstates

$$| B_{1,2} \rangle = \frac{1}{\sqrt{| p |^2 + | q |^2}} \left(p | B^0 \rangle + q | \overline{B^0} \rangle \right) , \tag{2}$$

where

$$\frac{q}{p} = \left(\frac{M_{12}^* - \frac{i}{2} \Gamma_{12}^*}{M_{12} - \frac{i}{2} \Gamma_{12}} \right)^{\frac{1}{2}} . \tag{3}$$

whose masses are given by

$$M_{1,2} = M \pm \mathrm{Re} \sqrt{\left(M_{12} - \frac{i}{2} \Gamma_{12} \right) \left(M_{12}^* - \frac{i}{2} \Gamma_{12}^* \right)} \tag{4}$$

with

$$\Gamma_{1,2} = \Gamma \pm \mathrm{Im} \sqrt{\left(M_{12} - \frac{i}{2} \Gamma_{12} \right) \left(M_{12}^* - \frac{i}{2} \Gamma_{12}^* \right)} \tag{5}$$

have now comparable lifetime, because many decay modes are common to both states and therefore the available phase space is similar. (Here we use the convention that B^0 contains a b quark, thus $\mathrm{CP} | B^0 \rangle = - | \overline{B^0} \rangle$).

A measure of the mixing is given by r and $\overline{r}$, the ratios of the total (time-integrated) probabilities

$$r = \left| \frac{p}{q} \right| \frac{\Delta M^2 + \left(\frac{1}{2} \Delta \Gamma \right)^2}{2\Gamma^2 + \Delta M^2 - \left(\frac{1}{2} \Delta \Gamma \right)^2} \tag{6}$$

$$\overline{r} = \left| \frac{q}{p} \right| \frac{\Delta M^2 + \left(\frac{1}{2} \Delta \Gamma \right)^2}{2\Gamma^2 + \Delta M^2 - \left(\frac{1}{2} \Delta \Gamma \right)^2} \tag{7}$$

where $\Delta M = M_1 - M_2$ and $\Delta \Gamma = \Gamma_1 - \Gamma_2$

The dilepton charge asymmetry, i.e. the asymmetry between the number of l^+l^+ and l^-l^- pairs produced is defined as

$$a_{\mathrm{SL}} \equiv \frac{N(l^+l^+) - N(l^-l^-)}{N(l^+l^+) + N(l^-l^-)} \tag{8}$$

and it is easily found to be

$$a_{\text{SL}} = \frac{|p/q|^2 - |q/p|^2}{|p/q|^2 + |q/p|^2} = \frac{\text{Im}\,(\Gamma_{12}/M_{12})}{1 + \frac{1}{4}\,|\Gamma_{12}/M_{12}|} \simeq \text{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right) \tag{9}$$

This approximation holds if $|\Gamma_{12}/M_{12}| \ll 1$ which is the case for the $B^0\text{-}\overline{B^0}$ system even in the presence of new physics. In order for this relation to be violated, one needs a new dominant contribution to the tree decays of b mesons, which is extremely unlikely or strong suppression of the mixing compared to the Standard Model box diagram, which is also unlikely.

Unfortunately, this $\Delta B = 2$ asymmetry is expected to be quite tiny in the Standard Model, because $|\Delta\Gamma/\Delta M| \simeq |\Gamma_{12}/M_{12}| \ll 1$ ($\Delta M \equiv M_{B_1} - M_{B_2}$, $\Delta\Gamma \equiv \Gamma_1 - \Gamma_2$). This can be easily understood by looking to the relevant box diagrams contributing to the $B^0\text{-}\overline{B^0}$ transition. The mass mixing is dominated by the top-quark graphs, while the decay amplitude get obviously its main contribution from the $b \to c$ transition. Thus,

$$\frac{\Gamma_{12}}{M_{12}} \simeq \frac{3\pi}{2}\frac{m_b^2}{m_t^2}\frac{1}{S(x_t)} \ll 1 \tag{10}$$

where $S(x_t)$ [7] is a slowly increasing function of x_t ($S(0) = 1$, $S(\infty) = 1/4$). One has then (see Eq.(3))

$$\left|\frac{q}{p}\right| \simeq 1 + \frac{1}{2}\left|\frac{\Gamma_{12}}{M_{12}}\right|\sin\phi_B \tag{11}$$

where

$$\sin\phi_B \equiv \arg\left(\frac{M_{12}}{\Gamma_{12}}\right) \tag{12}$$

The factor $\sin\phi_B$ involves and additional GIM suppression

$$\sin\phi_B \simeq \frac{8}{3}\frac{m_c^2 - m_u^2}{m_b^2}\text{Im}\left(\frac{V_{cb}V_{cq}^*}{V_{tb}V_{tq}^*}\right) \tag{13}$$

implying a value of $|q/p|$ very close to 1. Here $q \equiv d, s$ denote the corresponding CKM matrix elements for B_q^0 mesons. Therefore, one expects,

$$a_{\text{SL}} \leq \begin{cases} 10^{-3} & (B_d^0) \\ 10^{-4} & (B_s^0) \end{cases} \tag{14}$$

within the Standard Model. Thus, a lepton asymmetry in excess of these values is required in order to test new physics. Therefore, in this work this will be our smoking-gun.

Another useful quantity to look at is the total lepton charge asymmetry, which is defined by

$$l^{\pm} \equiv \frac{N(l^+) - N(l^-)}{N(l^+) + N(l^-)} = \frac{N(l^+l^+) - N(l^-l^-)}{N(l^+l^+) + N(l^-l^-) + N(l^+l^-) + N(l^-l^+)} \tag{15}$$

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This quantity is smaller than a_{SL}, but should be measured with better statistics. Unlike Eq.(9) which is true whether or not B^0-$\overline{B^0}$ is produced coherently, the total lepton charge asymmetry has a different form when expressed in terms of r and $\overline{r}$ in the case of a coherently or incoherently produced B^0-$\overline{B^0}$ pair. When it is produced coherently, the total lepton asymmetry is given by

$$l^{\pm} = \frac{r - \overline{r}}{2 + r + \overline{r}} \sim \begin{cases} .18\ a_{\text{SL}} & (B_d^0) \\ .43\ a_{\text{SL}} & (B_s^0) \end{cases} \tag{16}$$

where we have quoted the B_s^0 value for completeness as in the B-factories, just the B_d^0-$\overline{B^0}_d$ can be coherently produced. When the B^0-$\overline{B^0}$ is produced incoherently, the total lepton asymmetry becomes

$$l^{\pm} = \frac{r - \overline{r}}{1 + r + \overline{r} + r\overline{r}} \sim \begin{cases} .29\ a_{\text{SL}} & (B_d^0) \\ .49\ a_{\text{SL}} & (B_s^0) \end{cases} \tag{17}$$

The single lepton asymmetry measures the same quantity, $\text{Im}(\Gamma_{12}/M_{12})$, as the dilepton asymmetry. However, although as can be seen the prediction for the dilepton asymmetry is bigger, as both leptons must be tagged, the statistics is smaller.

3 The model

Left-right symmetric models [8] have been introduced more than twenty years ago as a natural extension of the standard model, mainly in order to justify on physical grounds the typical P-violating structure of weak interactions.

Starting from the gauge group $SU(2)_L \times SU(2)_R \times U(1)$ one is led to assume an initial left-right symmetry of the Lagrangian, by ascribing to the spontaneous symmetry breaking mechanism of the local gauge symmetry the natural basis of the maximal parity violation at low energies. As a consequence, parity restoration is to be expected beyond the mass scale at which the spontaneous breakdown is supposed to happen.

According to the left-right symmetry requirements, quarks (and similarly leptons) are symmetrically placed in left and right doublets

$$Q_{\alpha L} = \begin{pmatrix} u_{\alpha} \\ d_{\alpha} \end{pmatrix}_L \equiv \left(2, 1, \frac{1}{3}\right) \ , \quad Q_{\alpha R} = \begin{pmatrix} u_{\alpha} \\ d_{\alpha} \end{pmatrix}_R \equiv \left(2, 1, \frac{1}{3}\right)$$

where $\alpha = 1, 2, 3$ is the generation index, and the representation content with with respect to the gauge group is explicitly indicated.

Similarly, gauge vector bosons consist of two triplets $\mathbf{W}_L \equiv (3, 1, 0)$, $\mathbf{W}_R \equiv (1, 3, 0)$, and a singlet $B^{\mu} \equiv (1, 1, 1)$. While the scalar content of the minimal model is given by a complex bidoublet $\phi \equiv (2, 2, 0)$ and one set of left-right symmetric lepton-number carrying triplets $\Delta_L \equiv (3, 1, 2)$ and $\Delta_R \equiv (1, 3, 2)$. (A model with only a minimal scalar sector and spontaneous CP violation predicts unacceptably large FCNC [9], and it is because of this that one should add scalar triplets but these do not affect our analysis). The vacuum expectation values of the fields have the following form,

$$\langle\phi\rangle = \begin{pmatrix} k & 0 \\ 0 & k'e^{i\alpha} \end{pmatrix}$$

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$$\langle \Delta_L \rangle = \begin{pmatrix} 0 & 0 \\ 0 & v_L \end{pmatrix} \tag{18}$$

$$\langle \Delta_R \rangle = \begin{pmatrix} 0 & 0 \\ 0 & v_R e^{i\theta} \end{pmatrix}$$

The relative phases between k and k', α, and between v_L and v_R, θ, spontaneously break CP. However the leptonic sector does not concern us here, then, α will be the only source of CP violation. Eventually, there are seven CP violating phases in the mass eigenbasis, but they are all proportional to α.

In the Standard Model, the dominant contribution to $B^0 - \overline{B^0}$ mixing arises from the top quark contribution to the box diagram. Let us assume that the off diagonal element of $B_q^0 - \overline{B^0}_q$ is changed by a factor Δ_{qb} as a result of a new contribution from the left-right symmetric model

$$M_{12} = M_{12}^{(SM)} \Delta_{qb} \qquad (q = d, s) \tag{19}$$

where $M_{12}^{(SM)}$ is the standard (LL) box contribution which is given by [10]

$$M_{12}^{SM} \simeq \frac{G_F^2}{12\pi^2} B_B f_B^2 m_B M_1^2 \eta_2^{(B)} S(x_t)(\lambda_t^{LL})^2 , \tag{20}$$

where $\eta_2^{(B)} \simeq 0.83$ is a QCD correction factor, $S(x_t)$ is a well known Inami-Lim function and

$$\lambda_t^{AB} = V_{A,tl} V_{B,tb}^* \qquad (A, B = L, R) \tag{21}$$

while

$$\Delta_{qb} = 1 + \frac{M_{12}^{LR}}{M_{12}^{SM}}. \tag{22}$$

The left-right part gets its weight basically from three major sources, the first one is given by the $W_1 W_2$ box diagram which is also dominated by the tt exchange [11]

$$M_{12}^{W_1 W_2} \simeq \frac{G_F^2}{\pi^2} B_B M_1^2 \beta f_B^2 m_B \left(\left(\frac{m_B}{m_b + m_q} \right)^2 + \frac{1}{6} \right) \lambda_t^{RL} \lambda_t^{LR} \eta_1^{LR} F_1(x_t, x_b, \beta), \tag{23}$$

the second one is the $S_1 W_2$ box (S_1 denotes the Higgs boson that gives the longitudinal component to W_1)

$$M_{12}^{S_1 W_2} \simeq -\frac{G_F^2}{4\pi^2} B_B M_1^2 \beta f_B^2 m_B \left(\left(\frac{m_B}{m_b + m_q} \right)^2 + \frac{1}{6} \right) \lambda_t^{RL} \lambda_t^{LR} \eta_2^{LR} F_2(x_t, x_b, \beta) \tag{24}$$

with $\beta = M_1^2/M_2^2$, $x_i = m_i^2/M_1^2$ and the QCD coefficients $\eta_1^{LR} \approx \eta_2^{LR} \approx 1.8$.

F_1 is given by

$$F_1(x_t, x_b, \beta) = \frac{x_t}{(1 - x_t \beta)(1 - x_t)} \int_0^1 d\alpha \sum_k' \ln | \Lambda_k(\alpha, \beta) | \tag{25}$$

with

$$\sum_{k}{}' = \sum_{1,2} - \sum_{3,4} \qquad (26)$$

and the functions $\Lambda_k(\alpha, \beta)$ are defined by

$$\begin{aligned}
\Lambda_1(\alpha, \beta) &= x_t - x_b\alpha(1-\alpha) \,, \\
\Lambda_2(\alpha, \beta) &= 1 - \alpha + \frac{\alpha}{\beta} - x_b\alpha(1-\alpha) \,, \\
\Lambda_3(\alpha, \beta) &= x_t(1-\alpha) + \frac{\alpha}{\beta} - x_b\alpha(1-\alpha) \,, \\
\Lambda_4(\alpha, \beta) &= 1 - \alpha + x_t\alpha - x_b\alpha(1-\alpha) \,,
\end{aligned} \qquad (27)$$

and

$$F_2(x_t, x_b, \beta) = \frac{2x_t}{(1 - x_t\beta)(1 - x_t)} \int_0^1 d\alpha \sum_k{}' \Lambda_k(\alpha, \beta) \ln | \Lambda_k(\alpha, \beta) | \,. \qquad (28)$$

The last contribution is given by the tree level pieces which are mediated by the flavour changing neutral Higgs bosons ϕ_1 and ϕ_2 and their contribution is [12]

$$M_{12}^H \simeq -\frac{\sqrt{2}G_F}{M_H^2} m_t^2(m_b) B_B f_B^2 m_B \left(\left(\frac{m_B}{m_b + m_q} \right)^2 + \frac{1}{6} \right) \lambda_t^{RL}\lambda_t^{LR} \,, \qquad (29)$$

where we have assumed a common Higgs mass M_H.

Regarding Γ_{12}, as the tree level Higgs exchange does not contribute and all the terms containing a W_R have a suppressing β factor, the left-right contribution is completely negligible and we can take that $\Gamma_{12} \simeq \Gamma_{12}^{SM}$.

Consequently, it is clear that, because of the new contributions to M_{12}, the relative phase between Γ_{12} and M_{12} can now, unlike in the Standard Model case, be different. In fact, we have now that Δ_{bd}, which parameterizes the deviation from the Standard Model box diagram can be written as

$$\Delta_{bq} = 1 + \rho e^{i\sigma} \qquad (30)$$

where

$$\begin{aligned}
\rho &\equiv \left| \frac{M_{12}^{LR}}{M_{12}^{SM}} \right| \\
&= \frac{\beta \left(\left(\frac{m_B}{m_b + m_q} \right)^2 + \frac{1}{6} \right)}{12 S(x_t) \eta_2^{(B)}} \left(F_1(x_t, x_b, \beta)\eta_1^{LR} - \frac{1}{4}\eta_2^{LR} F_2(x_t, x_b, \beta) - \frac{\sqrt{2}m_t^2}{M_H^2 M_1^2 G_F} \right) \quad (31) \\
&\simeq \left[.21 + .13 \log\left(\frac{M_2}{1.6\text{TeV}} \right) \right] \left(\frac{1.6\text{TeV}}{M_2} \right)^2 + \left(\frac{12\text{TeV}}{M_H} \right)^2
\end{aligned}$$

and

$$e^{i\sigma} = \frac{\lambda_t^{LR}\lambda_t^{RL}}{(\lambda_t^{LL})^2} = -\frac{V_{R,tq}V_{R,tb}^*}{V_{L,tq}V_{L,tb}^*} \qquad (32)$$

with [5]

$$\sin \sigma^{(d)} \simeq \eta_d \eta_b r \sin \alpha \left[\frac{2\mu_c}{\mu_s} \left(1 + \frac{s_1^2 \mu_s}{2\mu_d} \right) + \frac{\mu_t}{\mu_b} \right] ,$$

$$\sin \sigma^{(s)} \simeq \eta_s \eta_b r \sin \alpha \left[\frac{\mu_c}{\mu_s} + \frac{\mu_t}{\mu_b} \right] , \tag{33}$$

to first order in $r \sin \alpha$ and

$$r = \frac{k}{k'} \quad , \quad \mu_i = \eta_i m_i \quad , \quad \eta_i^2 = 1 . \tag{34}$$

A detailed discussion of these formulae can be found in [13]. The important point to notice is that the predictivity of this model resides in the fact that by imposing spontaneous breakdown of CP, all the phases appearing in both V_L and V_R depend on α, as pointed out before. Besides that, due to the enhancement factor m_t/m_b in Eq. (33) it is easy to see that $\sigma^{(s),(d)}$ is by no means a suppression factor as can be naturally of order one. In fact, it has a lower bound (coming from the K system[6]) that ensures $| \sin \sigma^{(s),(d)} | \geq .2$ which guarantees that if nature is left right symmetric, this indeed will show up in CP asymmetries.

4 Results

We can now readily obtain an expression for the dilepton charge asymmetry in the left-right model,

$$a_{\mathrm{SL}} = \mathrm{Im} \left(\frac{\Gamma_{12}^{SM}}{M_{12}^{SM} + M_{12}^{LR}} \right) \simeq \left(\frac{\Gamma_{12}}{M_{12}} \right)_{SM} \left(-\frac{\rho \sin \sigma}{1 + 2\rho \cos \sigma + \rho^2} \right) \tag{35}$$

Of course, when the denominator of Eq.(35) vanishes, there exist other small contributions which eliminate the singularity. These contributions are proportional to β^2 and arise from the $W_2 - W_2$ and $W_1 - S_2$ box diagrams (S_2 denotes the Higgs boson that gives the longitudinal component to W_2).

The result in Eq.(35) shows explicitly that the dilepton charge asymmetry can be strongly enhanced over the Standard Model value. It is important to notice that such enhancement, which is larger when σ is larger, especially when σ is close to π, reaches its maximum when $\rho = 1$, for which it gives $1/2 \tan(\sigma/2)$. But values of ρ close to one are precisely the ones one expects in order to have a left-right symmetric model with low energy observable implications.

In Fig.1 we plot the value of ρ as a function of M_2 fixing the Higgs boson mass to 12 TeV and in Fig.2 as a function of M_H fixing the right-handed gauge boson mass to 1.6 TeV. From the figures, it can be easily seen that for Higgs and gauge boson masses close to their current lower bounds the enhancement is maximal.

We present the absolute value of the enhancement factor in Fig.3 for different values of ρ as a function of the spontaneous symmetry breaking phase α. With the chosen values for the masses, we conclude that left-right symmetry can enhance the dilepton charge

asymmetry (and hence also the total lepton charge asymmetry) for more than one order of magnitude.

At this point, it is important to notice that although in this work we are focusing ourselves on the lepton charge asymmetry as a means of searching for new physics, i.e. new physics in the mixing on the B-system to which these lepton asymmetries are sensitive, these new sources of mixing can be independently tested in other measurements. Particularly interesting alternative test for CP violation in the B-system are the study of the CP asymmetries in the $B_d \to J/\psi \, K_s$ and $B_d \to \pi^+ \, \pi^-$ decays, where new physics effects might be large and have been calculated by a large number of groups [14].

Even though these studies offer promising possibilities it will be very useful to have alternative means for searching new physics. Precisely because the rate in the Standard Model is negligible, the lepton asymmetries would be an extremely important measurement.

It should be emphasized that as the CP asymmetries in the decays $B_d \to J/\psi \, K_s$ and $B_d \to \pi^+ \, \pi^-$ are predicted (with a rather poor accuracy) to be sizeable in the Standard Model [15] (the CP asymmetries in B_s^0 decays which are supposed to be negligible small in the Standard Model cannot be studied in the B factories running at the Υ peak) a clear detection of new physics by their measurement alone is an extremely difficult task.

In the left-right symmetric model with spontaneous CP violation we are considering here, the B_d^0 CP asymmetries are given by

$$
\begin{aligned}
a_{J/\psi \, K_s} &= \sin\left(2\beta + 2\phi\right) \\
a_{\pi\pi} &= \sin\left(2\alpha + 2\phi\right)
\end{aligned}
\tag{36}
$$

where α and β are defined as usual

$$
\alpha \equiv \arg\left(-\frac{V_{L,td}V_{L,tb}^*}{V_{L,ud}V_{L,ub}^*}\right)
$$
$$
\beta \equiv \arg\left(-\frac{V_{L,cd}V_{L,cb}^*}{V_{L,td}V_{L,tb}^*}\right)
\tag{37}
$$

and

$$
\sin\phi = \frac{\rho\cos\sigma^{(d)}}{1 + 2\rho\cos\sigma^{(d)} + \rho^2}
\tag{38}
$$

As can be seen from the above formulae, even if in this case the new physics effect is big (notice however that the enhancement factor here is smaller than in a_{SL}) it cannot change drastically the value of the CP asymmetries because they are already expected to be of order one within the Standard Model.

Nevertheless new physics coming from the left-right model can change the sign of the CP asymmetries and this indeed will be a clear signal of physics beyond the Standard Model. In any case, the measurement of both, the CP asymmetries in B_d^0 decays and a_{SL} can prove (or disprove) the left-right symmetric model due to the existence of a strong correlation between them, as it is evident from Eq.(35) and Eq.(38).

5 Conclusions

In summary, it would be very interesting to perform an accurate measurement of the single lepton and/or the dilepton asymmetries. The presence of new physics in $B_d^0 - \overline{B}_d^0$ mixing can enhance the magnitude of a_{SL} to an observable level. For instance, $\mid a_{\mathrm{SL}} \mid \sim 10^{-2}$ can be achieved within the left-right symmetric model with spontaneous CP violation when the right-handed gauge boson and the flavour changing Higgs boson masses are close to their present lower bound. The reason is that while the relative phase between the Standard Model quantities M_{12}^{SM} and Γ_{12} is negligible, the relative phase between any of them and the left-right contribution M_{12}^{LR} can be quite large.

If the CP asymmetry a_{SL} is really of the order of 10^{-2} it should be detected at the forthcoming B meson factories, where as many as 10^8 $B_d^0 - \overline{B}_d^0$ events per year will be produced at the Υ resonance. In fact, the experimental sensitivities to a_{SL} are expected to be well within few percent for both single lepton or dilepton asymmetry measurements [16], provided the number of $B_d^0 - \overline{B}_d^0$ exceeds 10^7.

Of course the lepton asymmetries are correlated with the CP asymmetries in the $B_d \rightarrow J/\psi \; K_s$ and $B_d \rightarrow \pi^+ \; \pi^-$ processes. Measuring such a correlation may partly testify or rule out the left-right symmetric model with spontaneous CP violation.

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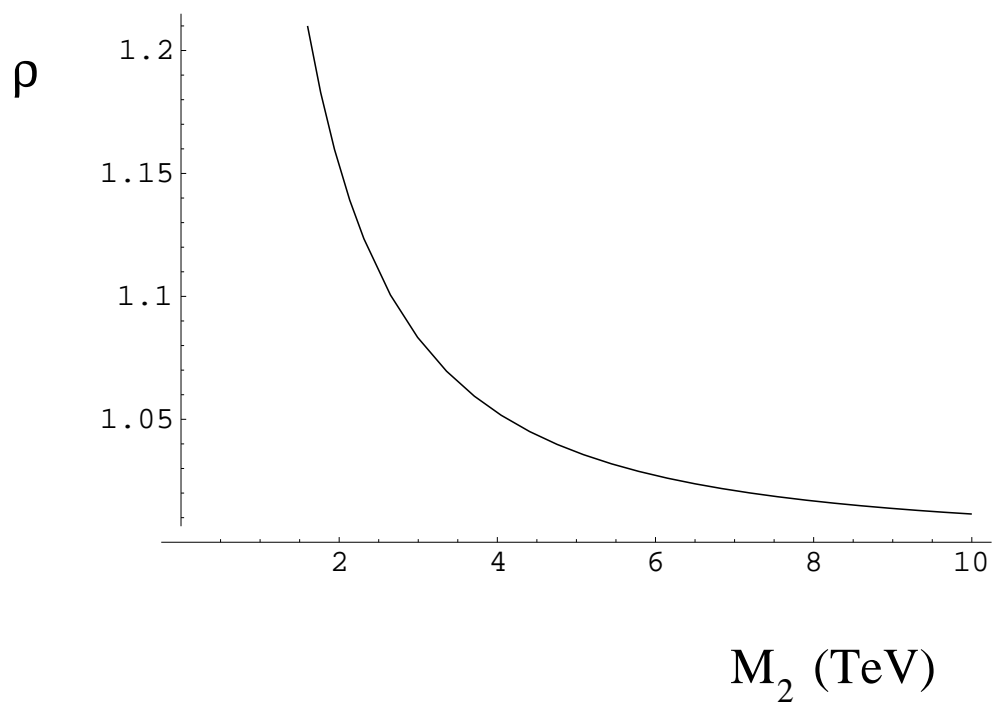
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Figure 1: ρ as a function of the right-handed gauge boson mass for a fixed $M_H = 12$ TeV.
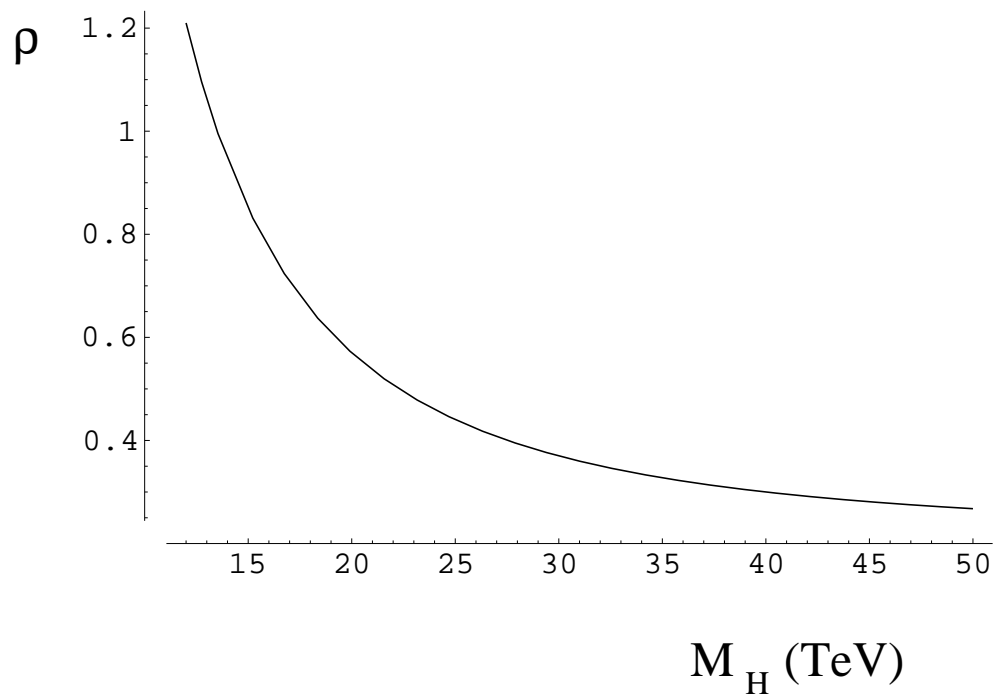
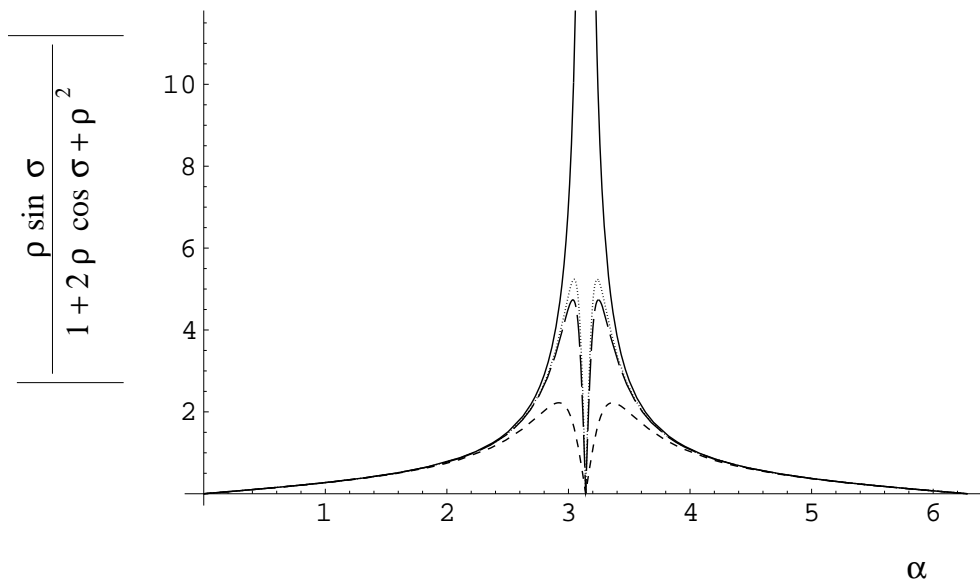Figure 2: ρ as a function of the flavour changing Higgs boson massfor a fixed $M_2 = 1.6$ TeV.

Figure 3: Absolute value of the enhancement factor, $\frac{\rho \sin \sigma}{1+2\rho \cos \sigma + \rho^2}$ as a function of the spontaneous symmetry breaking phase α for ρ=.8 (small dashed line), .9 (big dashed line), 1 (solid line), 1.1 (dotted line).

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